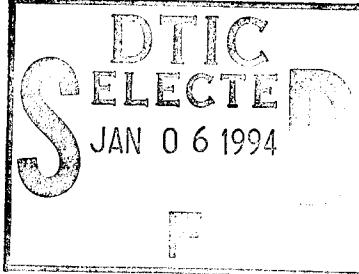


REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

| | | |
|--|---|---|
| 1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE 16 Dec 1994 | 3. REPORT TYPE AND DATES COVERED |
| 4. TITLE AND SUBTITLE Test Operations Procedure (TOP) 2-2-613 Electromagnetic Interference Testing and Electrical Subsystem - Non-Communication | | 5. FUNDING NUMBERS WU A268445 |
| 6. AUTHOR(S) | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Commander U.S. Army Combat Systems Test Activity ATTN: STECS-AC-I Aberdeen Proving Ground, MD 21005-5055 | | 8. PERFORMING ORGANIZATION REPORT NUMBER TOP 2-2-613 |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Commander U.S. Army Test and Evaluation Command ATTN: AMSTE-CT-T Aberdeen Proving Ground, MD 21005-5055 | | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER Same as Item 8 |
| 11. SUPPLEMENTARY NOTES Defense Technical Information Center (DTIC), AD NO: A 286 591 | | |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited. | 12b. DISTRIBUTION CODE | |
| 13. ABSTRACT (Maximum 200 words) This TOP describes procedures for conducting Electromagnetic Interference (EMI) tests of Non-Communication Electronic Equipment (NCEE) and Mobile Equipment Power (MEP) sources. | | |
|   <p>19950104 106</p> <p>DTIC SELECTED JAN 06 1994</p> | | |
| 14. SUBJECT TERMS Electromagnetic Interference Mobile equipment Conducted Emissions Radiated emissions Radiated susceptibility Intrasytem compatibility | | 15. NUMBER OF PAGES 23 |
| 16. PRICE CODE | | |
| 17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT |
| | | 20. LIMITATION OF ABSTRACT SAR |

U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure (TOP) 2-2-613
AD No. A286591

16 December 1994

ELECTROMAGNETIC INTERFERENCE TESTING FOR VEHICLES AND ELECTRICAL SUBSYSTEMS - NON-COMMUNICATIONS

1. SCOPE.

This TOP describes procedures for conducting electromagnetic interference (EMI) tests of non-communications electronic equipment (NCEE) and mobile equipment power (MEP) sources. The NCEE category includes tracked and wheeled vehicles, material-handling equipment (forklifts and cranes), commercial electrical and electromechanical equipment, and engineering equipment (bulldozers, graders, etc.). MEP sources are engine-driven power generators. The methods, procedures, and limits described in the TOP are confined to EMI testing in accordance with MIL-STD-461^{1**} and MIL-STD-462², including all subsequent notices and revisions. Supplements to this TOP will be published whenever revisions to the military standards occur which affect test procedures, instrumentation, or specification limits. This TOP applies to measuring conducted and radiated emissions and performing radiated susceptibility tests of NCEE and MEP equipment as well as the determination of intrasystem compatibility of the electronic, electrical, and electromechanical systems, subsystems, and components installed therein. The information provided in this TOP is intended for general guidance only. This TOP is limited to non-ionizing radiation.

*This TOP supersedes TOP 2-2-613, 12 October 1983

**Superscript numbers correspond to those in Appendix B.

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2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

The EMI tests may be conducted either at an open field test site on a conductive ground plane, in a shielded enclosure, or in an anechoic chamber large enough to contain the equipment under test (EUT) and meet the requirements of MIL-STD-462D³.

| <u>Item</u> | <u>Requirement</u> |
|--|--|
| Amplifiers/RF Generators | To be capable of developing frequencies and field intensity levels specified in MIL-STD-461 |
| Portable Radio Frequency absorber material | To place RF absorber loading as depicted in Figure 1, MIL-STD-462D to reduce reflections of electromagnetic energy and to improve accuracy and repeatability |
| Turntables | To rotate the test item during exposure tests to preclude the necessity to manually reposition the test item |

2.2 Instrumentation.

| <u>Devices for Measuring</u> | <u>Measurement Accuracy</u> |
|----------------------------------|---|
| Field Intensity | ± 3 dB of actual field intensity ± 2 % of actual frequency |
| Power line voltage and frequency | ± 0.5 % of reading (chart speed ± 0.25 %) |
| RF frequency | Frequency Resolution: 1 Hz Amplitude Resolution: 0.02 dB |

3. REQUIRED TEST CONDITIONS.

3.1 Test Planning.

a. Vehicles and NCEE. The test director must be thoroughly familiar with MIL-STD-461 and MIL-STD-462, including all subsequent notices and revisions. Tailoring of test requirements such as test distance, emission levels, and frequency range must be included in the test plan. Specific subtests may be identified in the Independent Evaluation Plan (IEP), the requirements document, the Test Execution Directive, and/or the Performance Specification. Any discrepancies among the documents should be resolved by the U.S. Army Materiel Systems Analysis Activity (AMSAA) independent evaluator

or TECOM independent assessor, the combat developer and project manager/materiel developer before proceeding with the test.

The following steps are essential:

- (1) Determine which subtests are required for the EUT.
- (2) Determine the distance from test antenna to the EUT (include this distance in the test plan). The appropriate MIL-STD lists the test distances required for the different types of equipment.
- (3) Determine the frequency range of the test and the specification limits. The appropriate MIL-STD gives the radiated emission frequency range and the specification limit curves to be used.
- (4) Determine the conducted emission requirements. The appropriate MIL-STD lists vehicles requiring conducted emission tests and gives the frequency ranges and specification limits.
- (5) Determine the method for testing to superseded specifications, if applicable. The appropriate MIL-STD provides information for testing vehicles classified as production-type equipment designed, tested, and certified to specifications other than MIL-STDs 461A⁴, 461A, NOTICE 4(EL)⁵, 461B⁶, 461C⁷, and 461D⁸.
- (6) Determine intrasystem compatibility requirements; these vary with each type of vehicle tested. An intrasystem compatibility matrix must be prepared based on the system/subsystem installed in the test vehicle. The matrix includes a list of all components, systems, and subsystems (culprits) that could cause interference with "on-board" systems (victims). The Project Manager or the contractor may be able to provide the intrasystem compatibility requirements, which could be used as a checklist or for comparison to the test director's independent matrix.
- (7) Determine radiated susceptibility requirements for vehicles equipped with electronic, electrical, or electromechanical subsystems. The appropriate MIL-STD provides information necessary for establishing the requirements for the radiated susceptibility test.

b. Mobile equipment power (MEP) generators. MIL-STD-461A, Notice 5⁹ or MIL-STD-461B/C, part 9, provides test requirements for radiated emission, conducted emission, and radiated susceptibility.

3.2 Test Item.

Ensure that:

- a. The EUT is fully equipped with all of its subsystems and systems.

b. All of the subsystems and systems are functioning normally.

c. The EUT is properly grounded and all electrical connections are tight.

3.3 Facilities.

Ensure that the facilities and instrumentation conform to the minimum requirements outlined in paragraph 2 of this TOP, and the appropriate MIL-STD.

3.4 Test Controls.

a. Determine which subtests are to be performed. Specific subtests may be identified in the Independent Evaluation Plan (IEP), the requirements document, the Test Execution Directive, and/or the Performance Specification. Any discrepancies among the documents should be resolved by the AMSAA independent evaluator or TECOM independent assessor, the combat developer and project manager/materiel developer before proceeding with the test.

b. Inspect the EUT to ensure that all of the radio frequency (RF) suppression systems, vehicle components, and electrical/electronic systems/subsystems are properly installed.

c. Check all components and electrical/electronic subsystems for proper functioning.

d. Record the nomenclature, model number, serial number and manufacturer of all electrical and electromechanical components that are potential sources of EMI.

e. Perform radiated and conducted emission testing using authorized instrumentation. A list of suggested test equipment or equivalent is given in MIL-STD-462.

4. TEST PROCEDURES.

4.1 Radiated Emission.

4.1.1 Method

a. Emplace the EUT at an open test site, in the center of the shielded enclosure, or in an anechoic chamber, and attach the enclosure exhaust system to the EUT if required.

b. If the EUT is an MEP, connect the output leads to a load bank.

c. Consult MIL-STD-462 for methods of performing electromagnetic interference tests.

d. After the EUT is emplaced in the open test site, shielded enclosure or anechoic chamber, position the appropriate sensors (antennas) at the required test distance from the EUT. Radiated emission measurements are made with the antennas positioned at a minimum of four locations around the EUT (front, rear, and each side).

e. De-energize the EUT and conduct an ambient scan of the test site over the frequency range of interest. Ensure that the ambient electromagnetic level is at least 6 dB below the allowable specified limit.

f. When testing a vehicle, start the vehicle engine, energize all electrical, electronic, and electromechanical equipment including electric windshield wipers, turn indicators, warning flashers, and headlights, to cause maximum radiation (worst-case condition). Scan the full frequency range and record the radiated emissions. Perform this test at engine idle speeds of approximately 700 rpm (slow idle) and 1400 rpm (fast idle).

g. If electromagnetic emissions from the EUT are detected above the specified limit, de-energize the individual subsystems one at a time until the offending subsystem(s) is (are) positively identified; then perform a separate test on each offending subsystem.

h. Use the procedures described above to conduct radiated emission tests of MEP sources. Take measurements with the MEP source operating at no-load, full load (1.0 power factor) and rated load (0.8 power factor) for all required voltage outputs.

4.1.2 Data Required.

a. Definition of EUT, including a component breakdown listing all potential sources of EMI emissions.

b. List of all instrumentation, antennas, and ancillary equipment used to perform the test, including calibration due dates.

c. Nomenclature, model number, serial number, antenna distance and all other pertinent test information recorded on Radiated Emission Log Sheet (fig. A-1, app A).

d. X-Y graphic recordings of radiated emission showing amplitude versus frequency with respect to the applicable specification limit recorded as a plot of radiated emission data for each load condition (fig. A-2, app A).

e. Tabulated results recorded on data sheets (fig. A-3 and A-4, app A), listing all RF emissions recorded above the applicable specification limit and containing the following:

- (1) Frequency (MHz)

- (2) Amplitude (dB μ V/M/MHz or dB μ V/M)
- (3) Cable loss (dB)
- (4) Transducer Factor (dB)
- (5) Broadband Correction Factor (dB)
- (6) dB above specification limit

4.2 Conducted Emission.

4.2.1 Method.

- a. Emplace the EUT in the center of the shielded enclosure or anechoic chamber, and attach the enclosure exhaust system to the EUT if required.
- b. If the EUT is an MEP source, connect the output leads to a load bank.
- c. Consult MIL-STD-462 for methods of performing electromagnetic interference tests.
- d. Emplace the EUT in the shielded enclosure or anechoic chamber, then clamp the current probe around the positive and negative battery leads or attach the coupling blocks to the positive and negative terminals of the battery of the EUT.
- e. De-energize the EUT and conduct an ambient scan of the test site over the frequency range of interest. Ensure that the ambient electromagnetic level is at least 6 dB below the allowable specified limit.
- f. When testing a vehicle, start the vehicle engine, energize all electrical, electronic, and electromechanical equipment, including electric windshield wipers, turn indicators, warning flashers, and headlights, to cause maximum radiation (worst-case condition). Scan the full frequency range and record the conducted emissions. Perform this test at engine idle speeds of approximately 700 rpm (slow idle) and 1400 rpm (fast idle).
- g. If electromagnetic emissions from the EUT are detected above the specified limit, de-energize the individual subsystems one at a time until the offending subsystem(s) is (are) positively identified; then perform a separate test on each offending subsystem.
- h. Use the procedures described above to perform conducted emission tests of MEP sources. Take measurements with the MEP source operating at no-load, full load (1.0 power factor) and rated load (0.8 power factor) for each conductor at each required voltage output.

4.2.2 Data Required.

- a. Definition of EUT, including a component breakdown listing all potential sources of EMI emissions.
- b. List of all instrumentation, coupling blocks or current probes, and ancillary equipment used to perform the test, including calibration due dates.
- c. Nomenclature, model number, serial number, and all other pertinent test information recorded on a Conducted Emission Log Sheet (fig. A-5, app A).
- d. X-Y graphic recordings of conducted emission showing amplitudes versus frequency with respect to the applicable specification limit recorded as a plot of conducted emission data for each load condition (fig. A-6, app A).
- e. Tabulated results recorded on conducted emission data sheets (fig. A-7 and A-8, app A) listing all RF emissions recorded above the applicable specification limit and containing the following:
 - (1) Frequency (MHz)
 - (2) Amplitude (dB μ A/MHz or dB μ A)
 - (3) Cable loss (dB)
 - (4) Transducer Factor (dB)
 - (5) Broadband Correction Factor (dB)
 - (6) dB above specification limit

4.3 Susceptibility Test.

4.3.1 Method.

Follow the procedures for performing radiated susceptibility tests described in detail in MIL-STD-462. To determine the threshold level of susceptibility when a malfunction occurs at the specified field intensity level, proceed as follows:

- a. Set the output of the signal source as low as possible.
- b. Operate the EUT to verify normal operation.
- c. While carefully monitoring the test item for malfunction, slowly increase the output of the signal source until the malfunction occurs. For MEP equipment, a voltage and frequency recorder connected to the generator output will be used as a monitor.

d. Measure the level at which the malfunction occurs and record as the "threshold level of susceptibility".

e. Repeat the above procedure at each frequency where a malfunction is observed.

4.3.2 Data Required.

a. List of all instrumentation, antennas, and ancillary equipment used to perform the test, including calibration due dates.

b. Test data recorded on Radiated Susceptibility Test Results data sheet (fig. A-9, app A) containing the following:

- (1) Sensor location with respect to EUT
- (2) Sensor polarization
- (3) Test frequency (MHz) for each malfunction
- (4) Modulation characteristics
- (5) Threshold levels (V/M)
- (6) Equipment reaction

4.4 Intrasytem Compatibility Test.

4.4.1 Method.

a. Emplace the EUT at an open field test site, in the center of the shielded enclosure or in an anechoic chamber and attach the enclosure exhaust system to the EUT if required.

b. Review the functional characteristics of the various subsystems of the EUT and categorize each subsystem as a potential source of electromagnetic interference EMI--culprit, or as a subsystem which might be a recipient and be affected by EMI--a victim, or as both a culprit and a victim.

c. Energize the first victim subsystem of the EUT and check for normal operation. Energize, operate, and de-energize each of the culprit subsystems individually while monitoring the victim for malfunctions or degradation of performance. Energize the second victim and repeat the above procedure. Repeat this procedure until all of the victims are tested against all of the culprits. Operate all of the culprits simultaneously and monitor all of the victims for any indications of compatibility problems.

4.4.2 Data Required.

- a. Description of the EUT, including nomenclature, model number, serial number, and all other pertinent test information.
- b. A component breakdown listing all potential culprits and victims recorded on an Intrasystem Compatibility Matrix (fig. A-10, app A).
- c. Each incidence of system malfunction or performance degradation will be recorded on data sheets with reference to the culprit.

5. PRESENTATION OF DATA.

5.1 Radiated Emission.

- a. Present X-Y graphic recordings (fig. A-2, app A) of radiated emission showing amplitude versus frequency with respect to the applicable specification limit.
- b. List the Nomenclature, model number, serial number, antenna distance and all other pertinent test information on a Radiated Emission Log Sheet (fig. A-1, app A).

5.2 Conducted Emission.

- a. Present X-Y graphic recordings (fig A-6, app A) of conducted emission showing amplitude versus frequency with respect to the applicable specification limit.
- b. List the Nomenclature, model number, serial number, and record all other pertinent test information on a Conducted Emission Log Sheet (fig. A-5, app A).

5.3 Susceptibility Testing.

Present these data on a Radiated Susceptibility Test Results Data sheet (fig. A-9, app A) which will include the following:

- (1) Sensor location with respect to EUT
- (2) Sensor polarization
- (3) Test frequency (MHz)
- (4) Modulation characteristics
- (5) Threshold levels (V/M)
- (6) Equipment reaction

TOP 2-2-613
16 December 1994

5.4 Intrasytem Compatibility.

Present a component breakdown listing all potential culprits and victims on an Intrasytem Compatibility Matrix data sheet (fig. A-10 app A). Present a listing of each system malfunction or performance degradation and the culprit system.

TOP 2-2-613
16 December 1994

APPENDIX A. DATA SHEETS

RADIATED EMISSION LOG SHEET

TEST ITEM: _____ SERIAL NO: _____

SERIAL NO: _____

MODEL NO: _____ SUBTEST NO: _____

SUBTEST NO: _____

MIL-STD: _____ ANTENNA DISTANCE: _____

ANTENNA DISTANCE: _____

Figure A-1. Radiated emission log sheet.

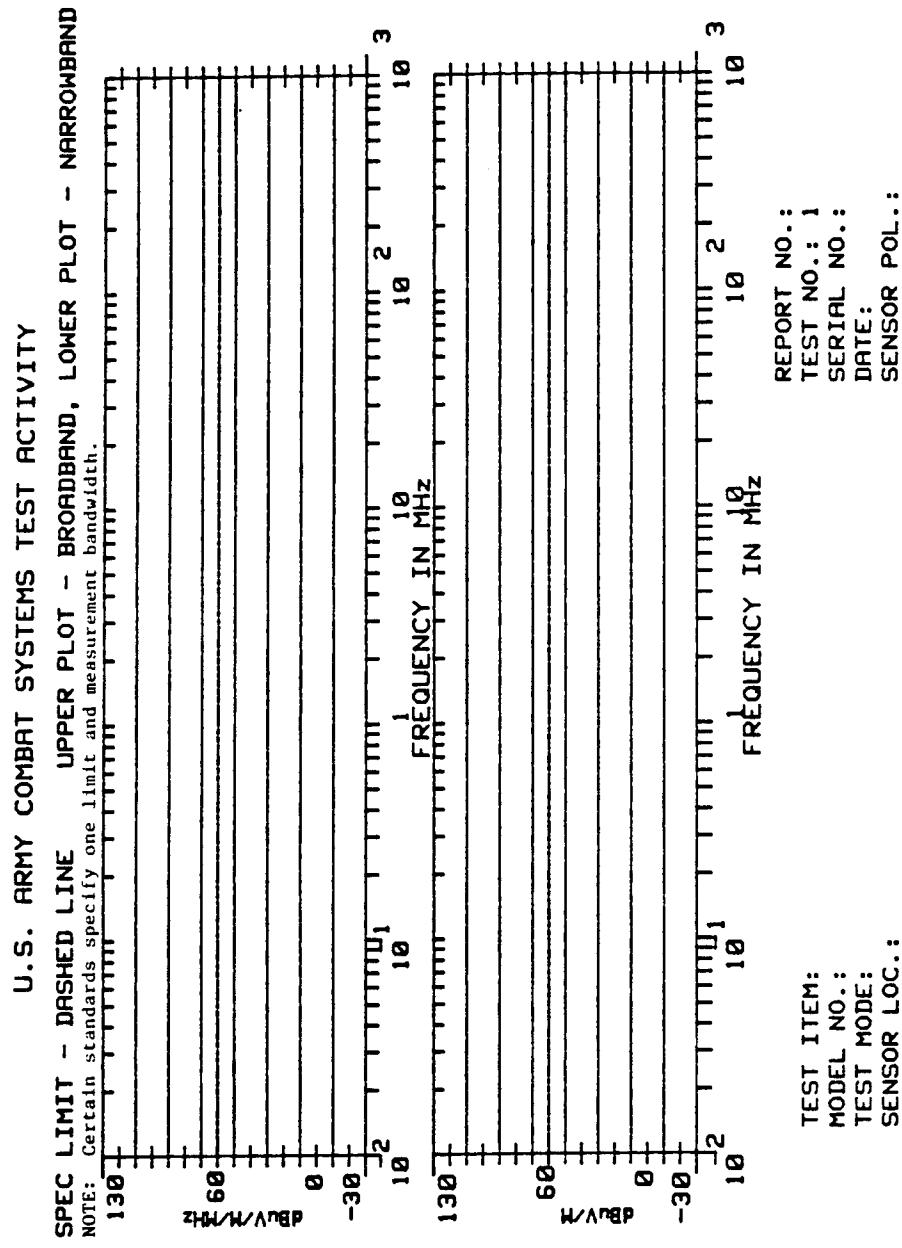


Figure A-2. Radiated emission graphic results.

A-2

TOP 2-2-613
16 December 1994

RADIATED EMISSION BROADBAND SIGNAL DATA

NOTE: Certain standards specify one limit and measurement bandwidth.

TEST ITEM: _____ DATE: _____

MODEL/TYPE: _____ TEST SETUP: _____

SERIAL NO: _____ ANTENNA LOC: _____

Figure A-3. Radiated emission broadband signal data sheet.

TOP 2-2-613
16 December 1994

RADIATED EMISSION NARROWBAND SIGNAL DATA

NOTE: Certain standards specify one limit and measurement bandwidth.

TEST ITEM: _____ DATE: _____

MODEL/TYPE: _____ TEST MODE: _____

SERIAL NO: _____ ANTENNA LOC: _____

Figure A-4. Radiated emission narrowband signal data sheet.

TOP 2-2-613
16 December 1994

CONDUCTED EMISSION LOG SHEET

TEST ITEM: _____ DATE: _____

DATE: _____

MODEL NO: _____ SUBTEST NO: _____

SUBTEST NO: _____

MIL-STD: _____ ANTENNA LOC: _____

ANTENNA LOC: _____

Figure A-5. Conducted emission log sheet.

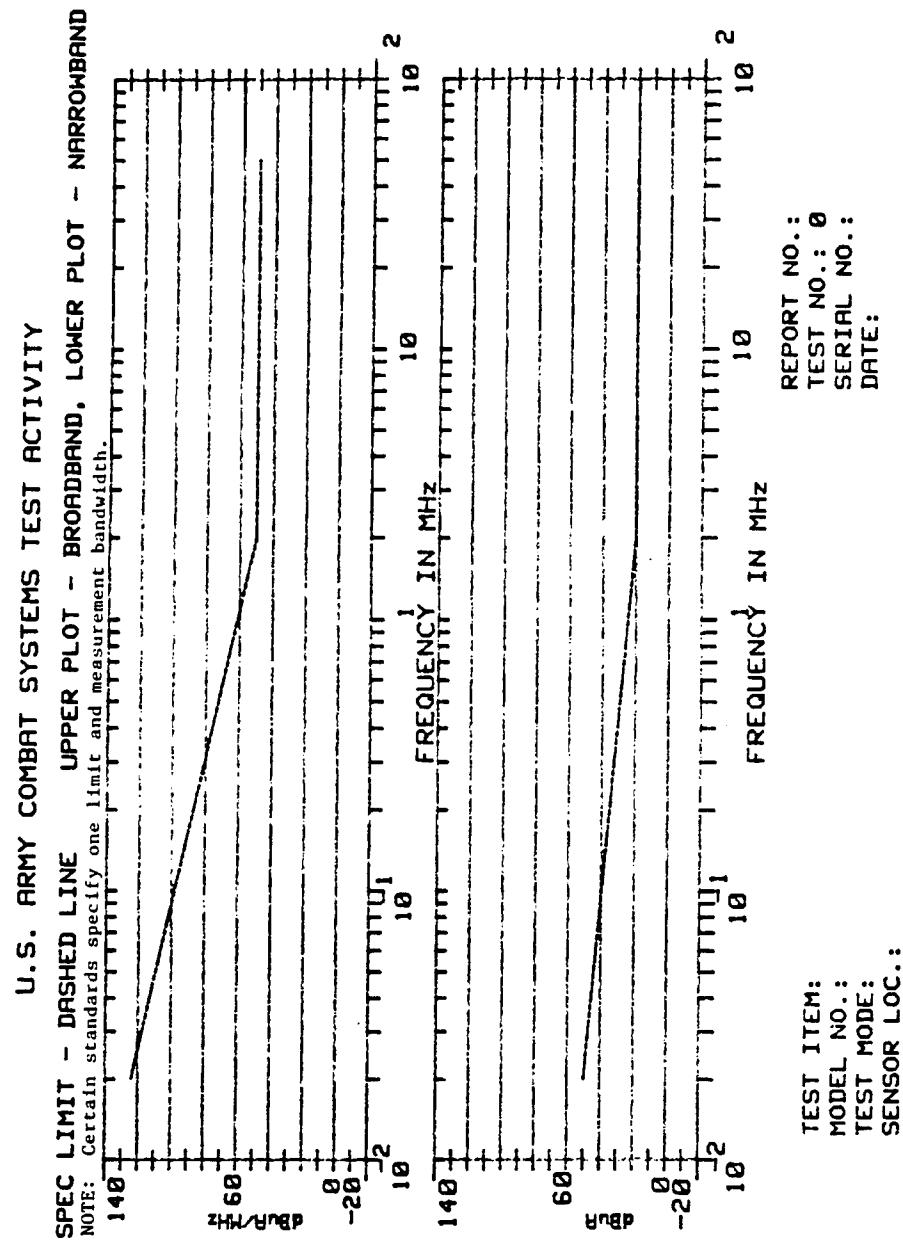


Figure A-6. Conducted emission graphic results.

TOP 2-2-613
16 December 1994

CONDUCTED EMISSION BROADBAND SIGNAL DATA

NOTE: Certain standards specify one limit and measurement bandwidth.

TEST ITEM: _____ DATE: _____

MODEL/TYPE: _____ TEST MODE: _____

SERIAL NO: _____ SENSOR LOCATION: _____

Figure A-7. Conducted emission broadband signal data sheet.

TOP 2-2-613
16 December 1994

CONDUCTED EMISSION NARROWBAND SIGNAL DATA

NOTE: Certain standards specify one limit and measurement bandwidth.

TEST ITEM: _____ DATE: _____

MODEL/TYPE: _____ TEST SETUP: _____

SERIAL NO: _____ SENSOR LOC: _____

Figure A-8. Conducted emission narrowband signal data sheet.

TOP 2-2-613
16 December 1994

RADIATED SUSCEPTIBILITY TEST RESULTS

TEST ITEM: _____ TEST MODE: _____

TEST MODE: _____

MODEL/TYPE: _____ SENSOR LOC: _____

SENSOR LOC: _____

SERIAL NO: _____ SENSOR POLAR: _____

SENSOR POLAR: _____

DATE: _____ MODULATION TYPE: _____

MODULATION TYPE: _____

Figure A-9. Radiated susceptibility test results data sheet.

Figure A-10. Intrasytem compatibility matrix data sheet.

A-10

APPENDIX B. REFERENCES

1. MIL-STD-461, "Electromagnetic Interference Characteristics, Requirements for Equipment, Subsystem, System", 31 July 1967.
2. MIL-STD-462, "Electromagnetic Interference Characteristics, Measurements of" 31 July 1967.
3. MIL-STD-462D, Measurement of Electromagnetic Interference Characteristics, 11 January 1993.
4. MIL-STD-461A, "Electromagnetic Interference Characteristics, Requirements for Equipment, Subsystem, System", 1 August 1968.
5. MIL-STD-461A, NOTICE 4(EL), "Electromagnetic Interference Characteristics, Requirements for Equipment, Subsystem, System", 9 February 1971.
6. MIL-STD-461B, "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference", 1 April 1980.
7. MIL-STD-461C, "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference", 4 August 1986.
8. MIL-STD-461D, Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility, 11 January 1993.
9. MIL-STD-461A, NOTICE 5, "Electromagnetic Interference Characteristics, Requirements for Equipment", 6 March 1973.

TOP 2-2-613
16 December 1994

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